

# SOAPS

Spectrum Opportunistic Access  
in Public Safety networks

*Resources Brokering between Neighboring Cells Mechanism  
for Cell-Edge Capacity Enhancements  
of a Broadband LTE based Public Safety Network*



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île de France

- Introduction to Public Safety Networks (or PMR)
- PMR 's next move to 4G: challenges !
- Presentation of the SOAPS project
- SOAPS: current studies & solutions
- Conclusion

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## Public Safety means :

- Protecting people and property while maintaining national security throughout the territory.
- That includes day-to-day law enforcement, fires and earthquakes to terrorist attacks, natural and man-made disasters ... and major events like G20, Olympic games, Football cups ...

→ Governments and Security agencies must rely on secured solutions for theses critical missions

- PMR or Professional Mobile Radios is the secured telecommunication system used in Public Safety Network !
- CASSIDIAN is the world leader with Motorola in PMR for Public Safety

*For example: ANTARES french radio network for firemen and urgent medical service. Based on Tetrapol technology, 1450 sites, 220 000 users and 70 000 mobiles*

- Current radio networks are based on technologies similar to 2G:
  - Mainly Voice
  - Tetrapol, TETRA & P25 Standards
  - Cellular networks with narrow-band channels (10,12.5, 25 KHz)
  - Very high performance digital voice in any situation (“extreme” sensitivity)
  - Low data capability: few kilobits per second
- But some important features for first responders:
  - Group calls capability with PTT : point to multipoints / multipoints to multi points
  - Direct Mode (DMO) between users or group of users:
    - works without infrastructure !
  - Relay mode



- These Networks have also some specificities that make them different from Commercial Networks:
  - Specific band of operation: around 400MHz in EU with 2x 5MHz bandwidth
    - Better signal propagation
  - Very Large Cells:
    - Limited cost of deployment (Public institutions or Government owned)
    - Result of good signal propagation
    - Secured locations
  - More Uplink than Downlink communications needs
    - Completely the opposite as Commercial Networks !
  - Low mean User density
    - Day-to-day operations / routine
  - The network may have a very high density of Users located on a small area
    - Major event case !
  - End-to-End encryption
  - Ruggedized equipments



TETRA I

TETRAPOL

P25 Ph1 &2

Mission-critical V+D

TETRA Enhanced Data  
Services

TETRAPOL Data  
Enhancements

High Speed data

Mission-critical  
high-speed data

Broadband PMR

@400MHz in EU  
@700MHz in the US



Mission-critical  
broadband

**Next years : Migration & Convergence of narrow-band digital Standards to Broadband Solutions with 4G LTE Technology**

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- **LTE technology** has been chosen as the standard for future broadband PMR:

LTE has impressive features:

- Spectrum flexibility: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz wide cells + Carrier aggregation (rel. 10+)
- Peak download rates up to 299.6 Mbit/s
- Peak upload rates up to 75.4 Mbit/s (with 4x4 antennas using 20 MHz of spectrum)
- MIMO 8x8
- ...



## • But for Public Safety applications:

- Very limited spectrum available for PS:
  - US: at most 5 MHz bandwidth
  - EU: at best 1.4MHz ! (5 MHz total bandwidth)
- Usage different from commercial general public use:
  - 85/15 vs. 50/50 up to 20/80 Downlink / Uplink ratio
  - Limited reliability of the service
  - NO concepts of group of users, direct mode communications ...
- Crisis Management vs. No more service
- Same Large cells as current Narrowband vs. higher cell density than 3G
- Day-to-day low users density & very high localized user density for major events

## • Concerning the Radio aspects compared to current systems:

- Frequency Re-Use of 1 vs. ~19
- Same power amplifier gain for 40 times more spectrum @ 1,4MHz
- Re-use of the same (secured) Base Station locations (density is increased for commercial networks / 3G)

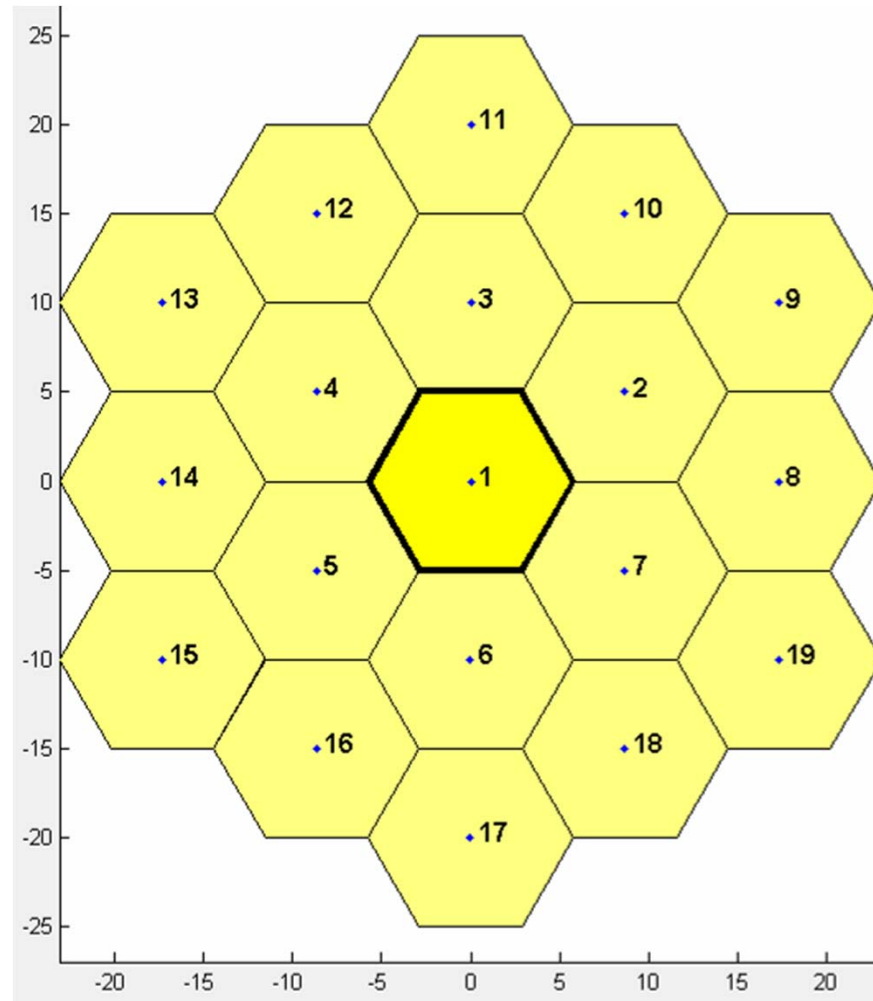
→ Natively less SNR & self-interferences due to adjacent cells

## • Example: 5 MHz LTE network

- Theoretical deployment
- Sub-Urban environment (Hata propagation)
- Omni directional eNodeBs
- 10 km intersite
- MIMO 2x2 (2x40W)
- Mobile 5W

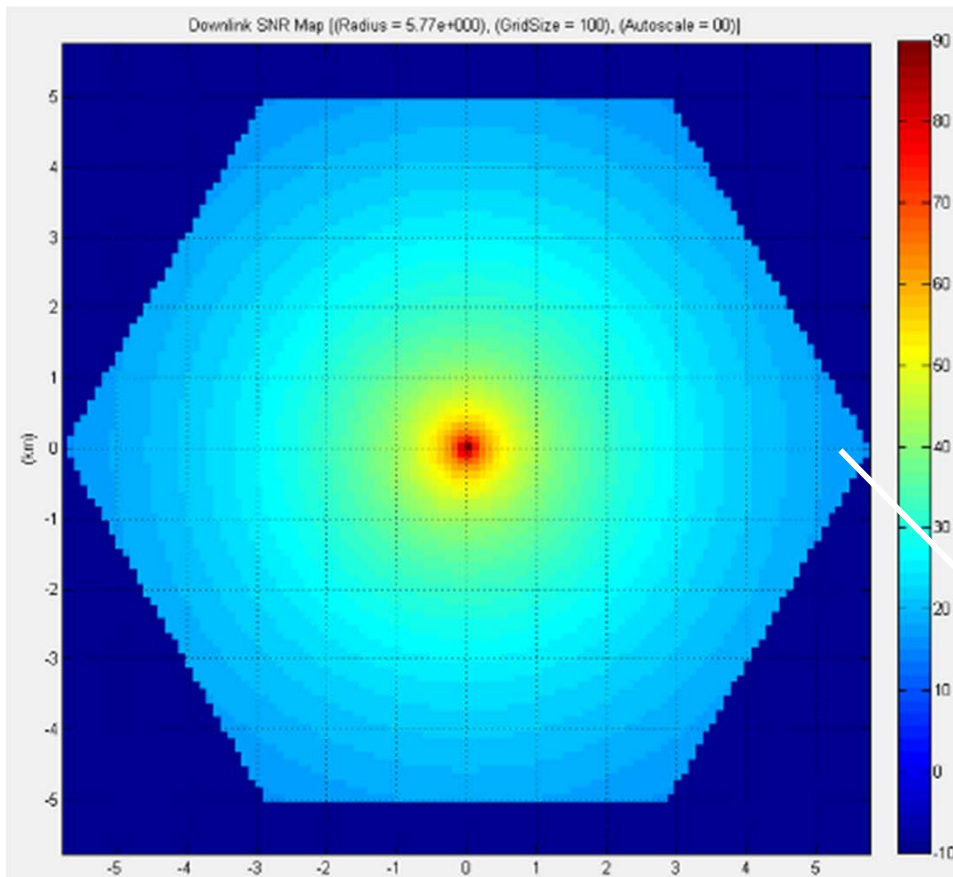
■ Capacity calculated with the Modified Shannon formula:

$$C = \alpha * W * \log_2 \left( 1 + \frac{SNR}{\beta} \right)$$

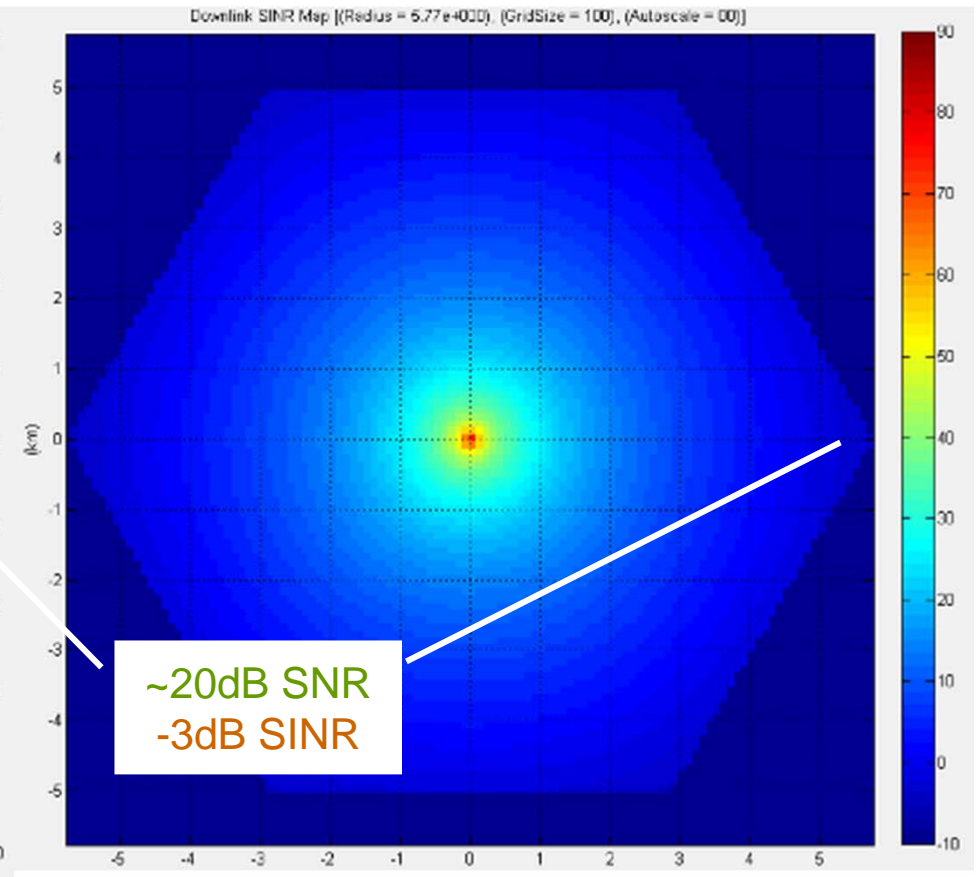


*Example: Downlink 4G LTE 5MHz @400MHz/ MIMO 2x2/ 5km cells*

SNR map (dB)

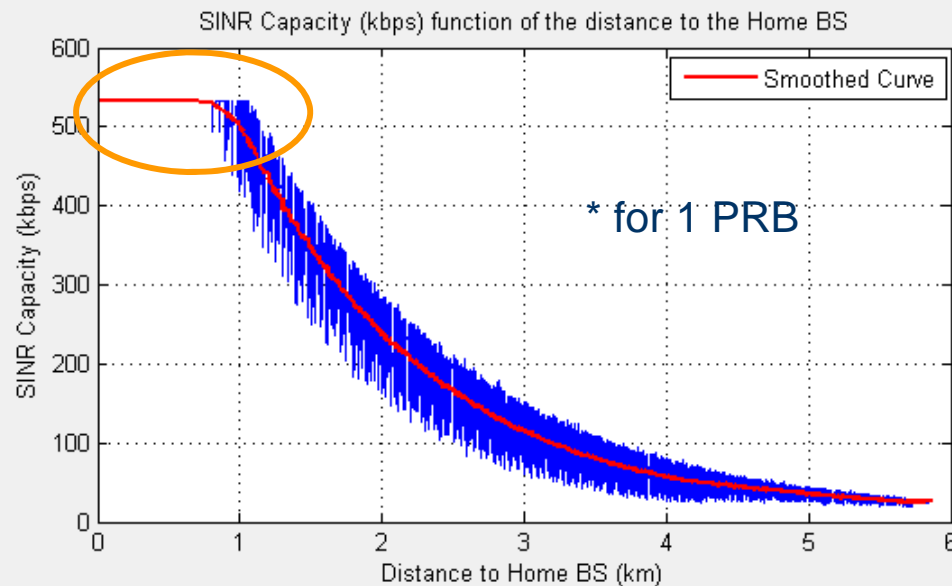
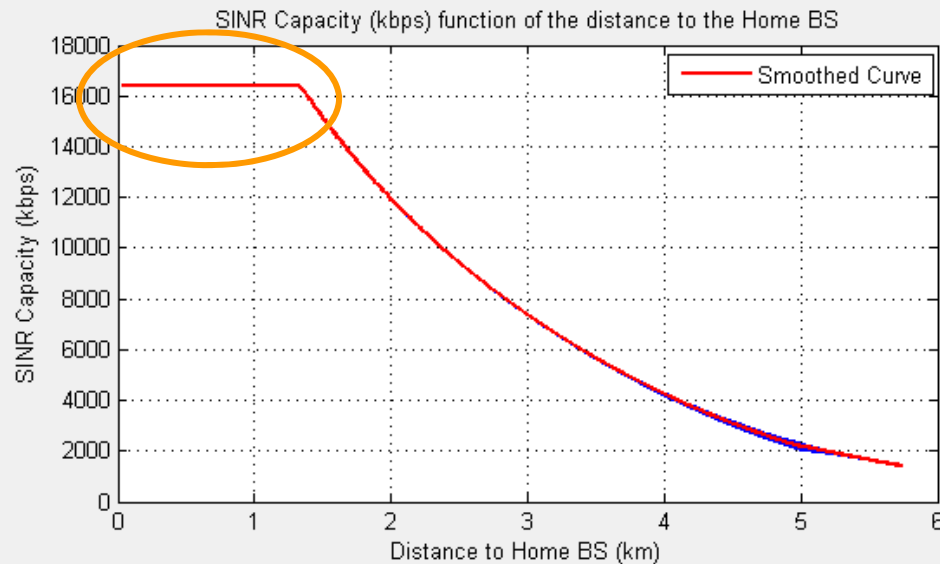


SINR map (dB)

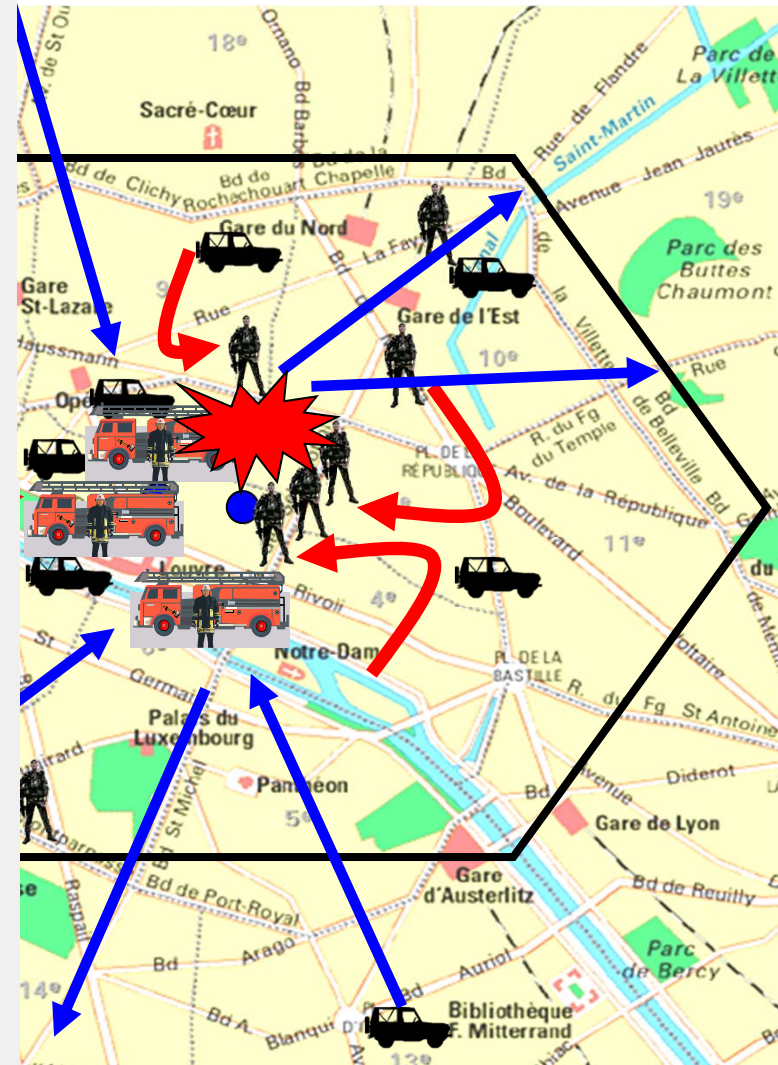


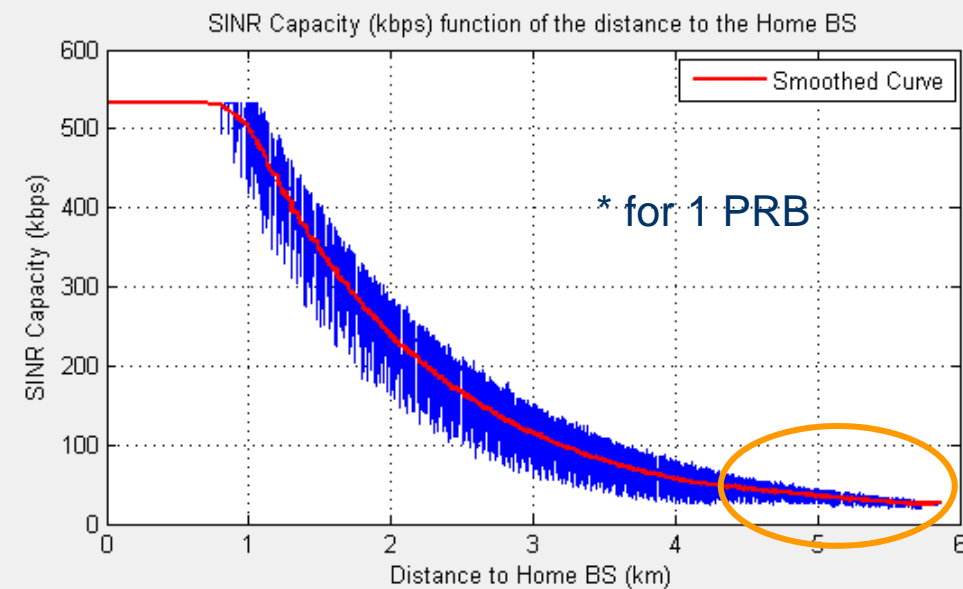
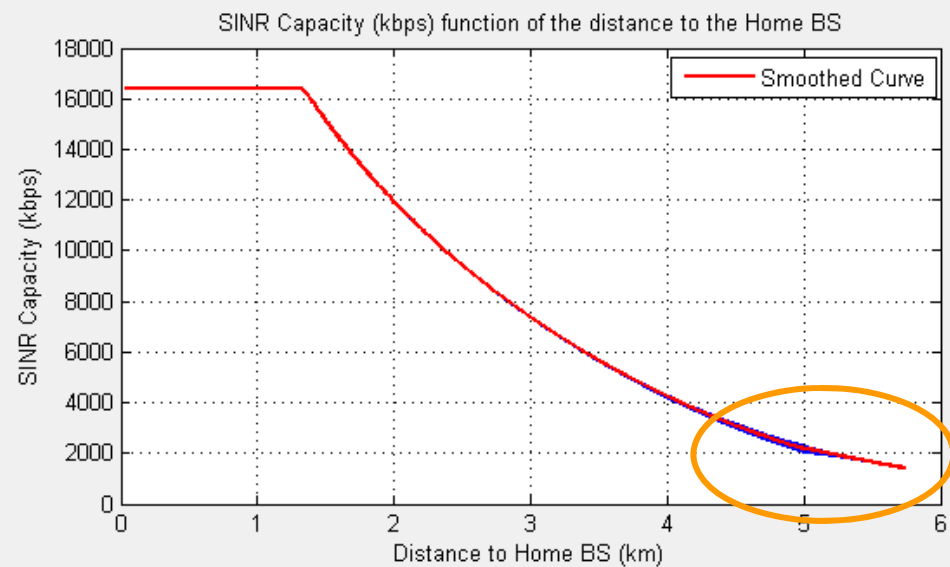
~20dB SNR  
-3dB SINR



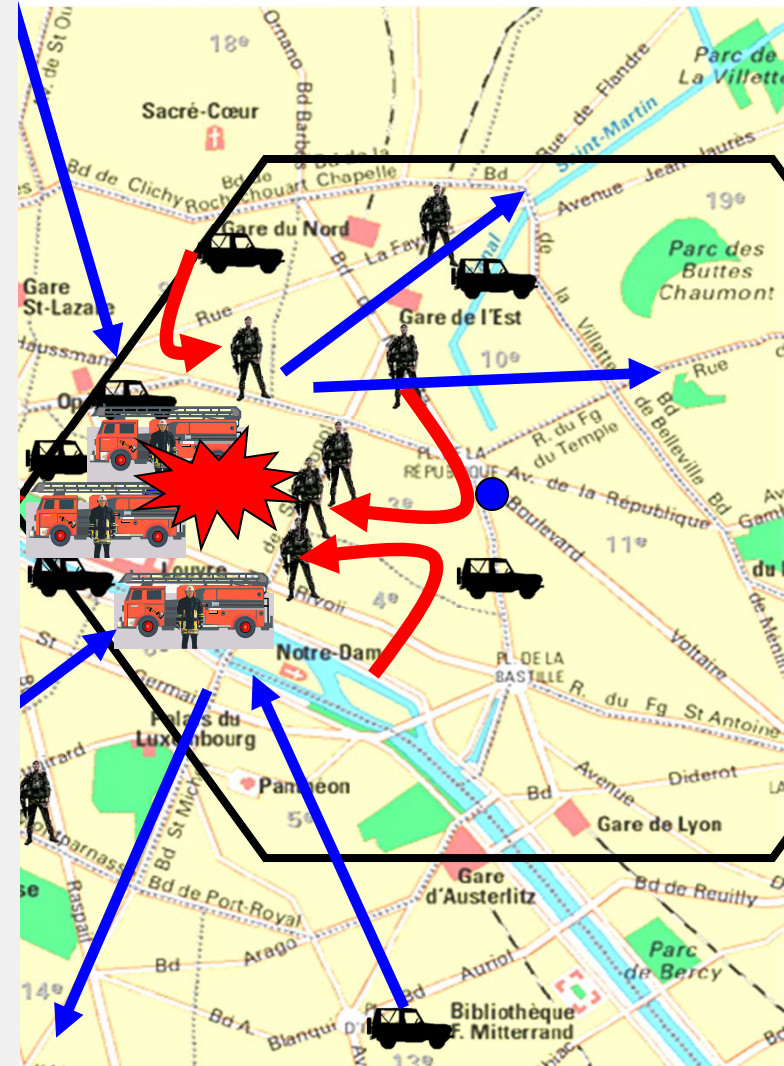


## for security event – Cell Center





## Major security event – Cell Edge



- Cell edges are mainly impacted by interferences from surrounding cells:
  - Huge decrease in performances
  - Lack of capacity coverage in case of major events with a strong density of users
- Solutions:
  - LTE Standard proposes interferences reduction mechanisms but
    - with a (very) limited collaboration between cells (Inter-Cell Interference Coordination – **ICIC**, **Overload Indicator**, **High Interference Indicator**, etc. ...)
    - and/or with bandwidth reduction mechanism in order to apply >1 frequency reuse schemes: **Hard & Soft frequency Re-use Schemes**
      - Nyquist - Shannon: more bandwidth is better than increasing the SINR !

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*Spectrum Opportunistic Access in a Public Safety Network*

SOAPS is a collaborative project supported by Systematic, the competitive cluster of



Yvelines  
Conseil général



***www.soaps2.fr***

36 Month project – 10M€ - 01/10/2011 start date

10 partners



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- *Phase 1: cohabitation*
  - *deployment of a standard 4G PMR network in parallel with current narrowband networks*
- *Phase 2: full broadband*
  - *Broadband PMR network with Public Safety specific features*

Innovation needed !

- → Phase 2 is the framework of the SOAPS project:
  - Scenarios: using the new operational capacities of the network
  - Physical layer enhancements:
    - **Better filtering for better waveform cohabitation**
    - **Interference mitigation using MIMO techniques**
    - **Cross-layering techniques for efficient voice & video transmissions over LTE**
  - Upper layers enhancements:
    - **Self-adaptive and autonomous resources management techniques**
  - Demonstrations:
    - Software demonstrator: simulator of the modified scheduler
    - Hybrid Software & Hardware demonstrator: demos in Elancourt with Cassidian 400MHz LTE cells

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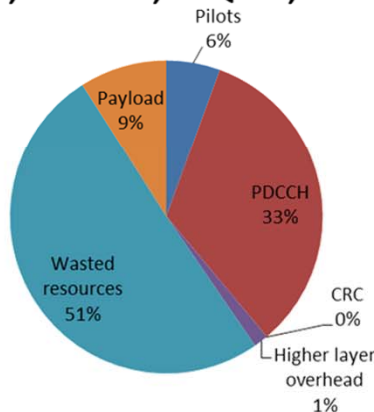
Reserved for NB  
network

Filterbank Based Multicarrier(FBMC)  
with OQAM Modulation

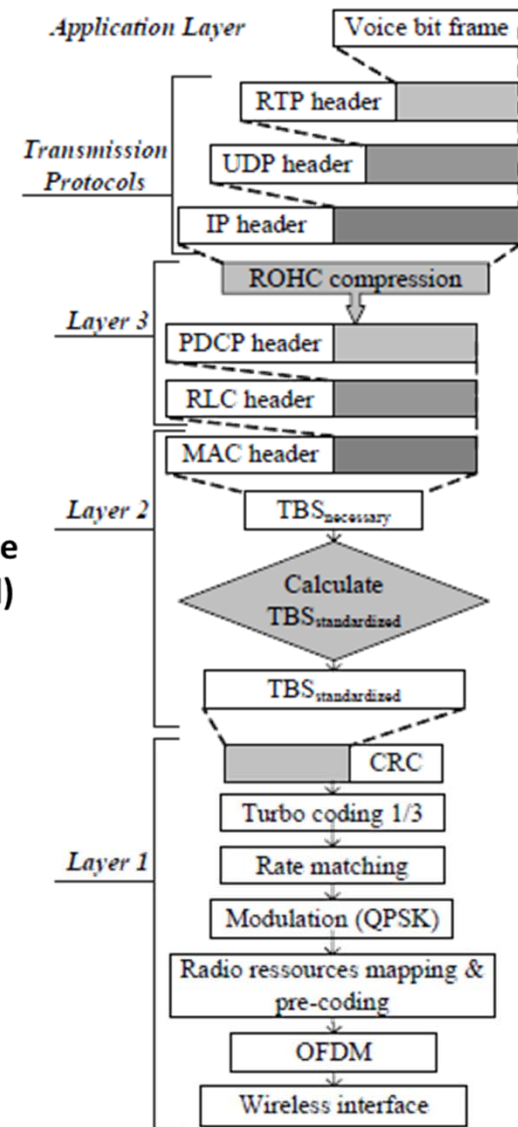
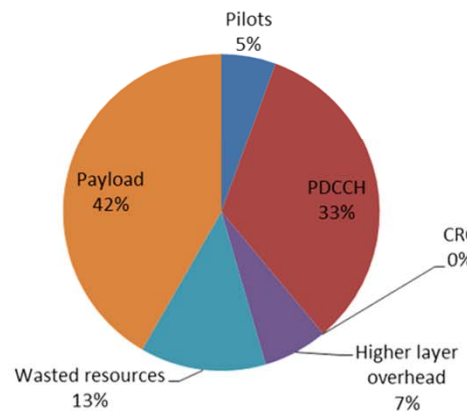
## • Low layers Studies:

- 2: MIMO / SIMO techniques for low VHF bands: gain through diversity @400MHz
- 3: Cross-layering techniques for more efficient Voice & Video transmission over LTE: less information bits wasting for smaller LTE channels (1,4 MHz )

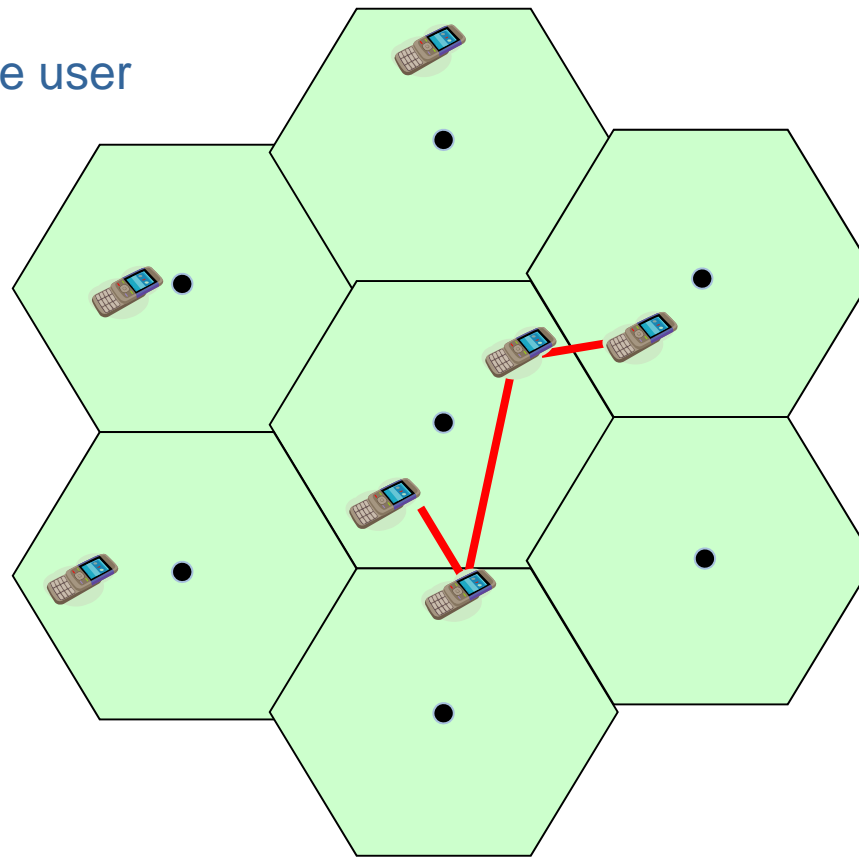
**Repartition of resources in a VoIP frame  
(ideal case, 1.4 MHz, 64QAM, 1 PRB used)**



**Repartition of resources in a VoIP frame  
(ideal case, 1.4 MHz, QPSK, 1 PRB used)**



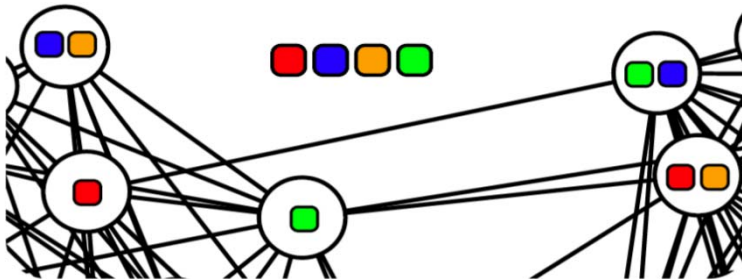
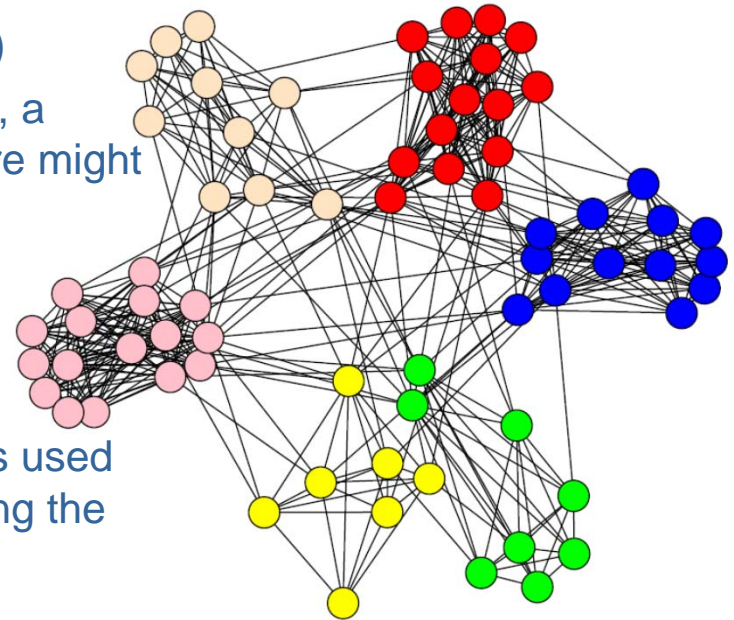
- Scheduling optimizations: objectives
  - To avoid at most the interferences between cells in a pro-active manner (compared to existing or studied passive algorithms)
  - To allocate the Resources (RBs) as of function of an operational need:
    - priority of the user
    - QoS
    - ...



- Scheduling optimizations: 2 solutions
  1. Spectrum sensing : each eNodeB ask the UEs for measurements – its own UEs and UEs of surroundings cells
  2. Each eNodeB broadcast these measurements to its neighboring cells
  
- 3. Then 2 methods to the distributed problem !
  - Cost function ( developed by CASSIDIAN )
    - For each UE an increasing cost function is defined depending on its priority level, its service class and its non satisfied requests
    - Then the problem is to minimize the sum of all cost functions of the network. This will act as resources brokering between cells, as cells will negotiate with their surrounding cells the usage of the resources
    - → Resources will be allocated in order to avoid or reduce the interferences globally on the network
    - → This algorithm is applied on a cyclic manner in order to operate a limited time-frequency block of resources.
  
  - Graph Theory ( developed by SUPELEC ) →

- Scheduling optimizations: 2 solutions

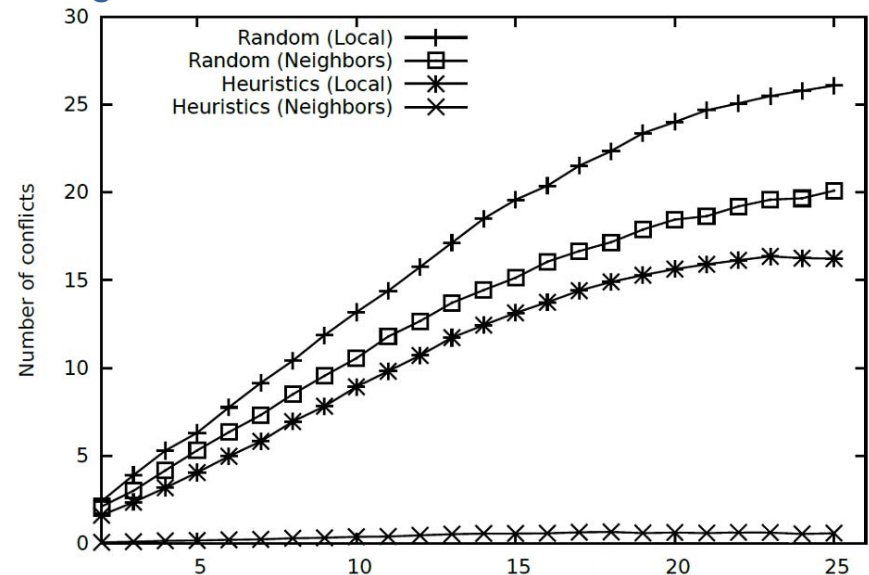
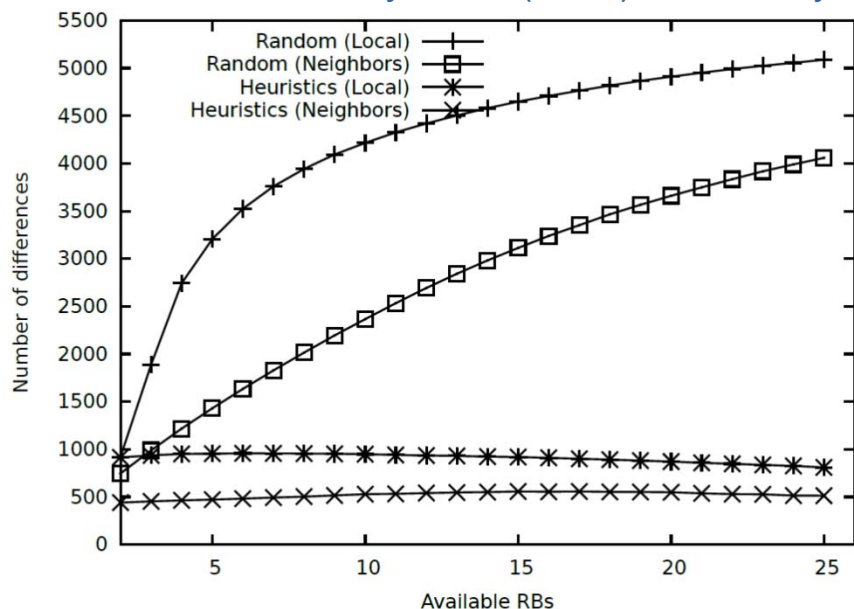
- Graph Theory ( developed by SUPELEC )
  - From interference capability measurements, a graph is build where 2 UEs are linked if there might interfere. (Uplink case)
- The Weighted Fractional Coloring Method is used for the solution : Resource allocation knowing the interference capabilities



- The colors represent the RBs
- 2 UEs can not get the same RB/color
- The color distribution is optimized



- Scheduling optimizations: 2 solutions
  - Graph Theory ( developed by SUPELEC )
    - NP-Complete problem
    - Need full knowledge of the graph and then heuristics are necessary for a deterministic allocation algorithm
    - Real case need a distributed algorithm: the heuristic is applied by one cell considering only its knowledge of the interference capability of its surround cells sensed by itself (local) or sent by its neighbors.



*Spatial Frequency Reuse in a Novel Generation of PMR Networks*, Alexis Lamiable and Joanna Tomasik, SUPELEC Systems Sciences (E3S), Computer Science Department (WCNC 2013)

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- 4G is the wireless technology for Next Generation Public Safety Networks.
- Specificities of PMR networks implies major changes in the LTE Standard.
- SOAPS project is an enabler to study and test new mechanisms and algorithms to enhance the 4G for PMR.
- Next step is to push the modifications to the 3GPP forum for a future LTE Standard release with Public Safety oriented features.

*Thank you for your attention !*